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Patterning sub-micron scale channel structures on glass by chemical etching

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Abstract : We report a soft lithography based approach in generating predetermined channel structures, in the form of parallel lines and cross patterns at the sub-micron scale, by chemical etching of glass slides. We have used the polycarbonate part of a commercially available compact disc as the mold to generate suitable imprints. The mold contains parallel lines in the form of crest and trough of submicron dimensions. Aqueous HF solution was used as the ink. This method of imprinting patterns generated a negative replica of crests and troughs on glass slides. Cross patterns with submicron scale channel structures could also be obtained if the slide was etched twice with the inked mold.

Keywords : Soft lithography, chemical etching.

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1. Introduction

The constant and growing endeavor in generating newer methodologies in nano-fabrication has led to the discovery of a plethora of techniques in this field [1,2]. Two and three dimensional structures and patterns at micro and nano meter length scales are routinely generated using soft lithography [3], micro and nano pen lithography [4], electron beam lithography [5], X-ray lithography [6] and also using scanning probe microscopes [7,8]. Guided fluid flow has also been used in generating structures inside microchannels [9]. Wet chemical etching is a common method to imprint nanoscale features on Si [10,11]. Guided growth inside micro-capillary can also generate sub-micron length structural features [12,13]. Laser-assisted direct imprint (LADI) method has been applied to obtain nanostructures in silicon [14]. On the other hand photolithographic and etching methods are combined to fabricate all-glass micro reactors [15]. However, none of the methods mentioned above has obtained structural features by simple chemical etching of a glass surface using a mold and an etching solution as the ink. This is important as structural features on a two-dimensional glass surface generated by etching can be used in the fabrication of microfluidic devices including microreactors. Conventional methods of making glass microreactors require many steps involving photolithography followed by chemical etching and curing.

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Here we report an inexpensive, one-step and simple method for generation of two-dimensional structural patterns on glass substrates by using a combination of soft lithography and chemical etching of glass with HF solution. The idea is to transfer the structural features of a mold to the substrate by inking the mold with HF solution and then pressing the mold on the glass surface. Submicron line features [16] of the polycarbonate disc of an ordinary compact disk (CD) has successfully been

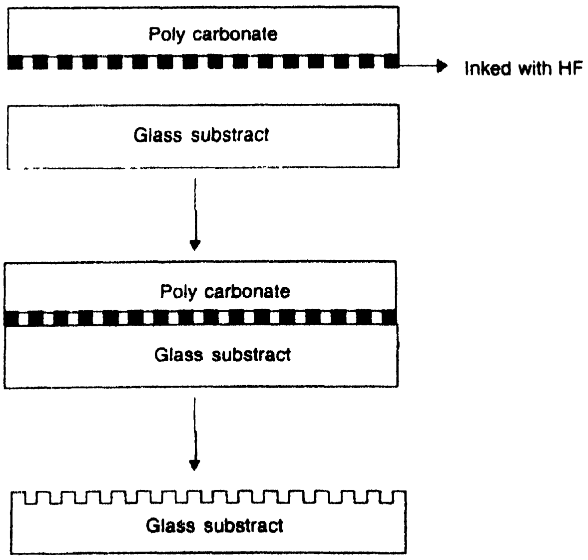


Figure 1. Schematic representation of the process of imprinting parallel lines on glass by chemical reaction etching.

transferred to glass surface in the form of parallel lines of channels and arrays of etched spots on the surface. The structural features thus obtained were observed by optical microscopy and scanning electron microscopy.

2. Experimental

Figure 1 shows schematically the new method of etching glass with features at the sub micron scales. Commercially available CDs were purchased and broken into pieces to obtain polycarbonate disks of about 50 mm x 25 mm sizes. Aqueous HF solution (6% v/v) was used as "ink" to wet the top surface of the disk (mold) using a cotton swab. The disk was then kept pressed using a home-made screw press, for 5 min, on to a previously cleaned (by piranha solution) microscope slide to etch parallel lines on it. The mold was removed; the glass slide was cleaned with water and then wiped dry with a tissue paper. The slide was ready for observation under microscope. The above process was repeated twice in sequence at different angles to obtain arrays of non-etched spots.

3. Results and discussions

Figure 2 represents typical optical micrograph of a polycarbonate disk that has been used as the mold in the present work. As clear from the picture, the mold consists of parallel lines of about 0.7 mm thick that are separated by about 0.8 mm gaps.

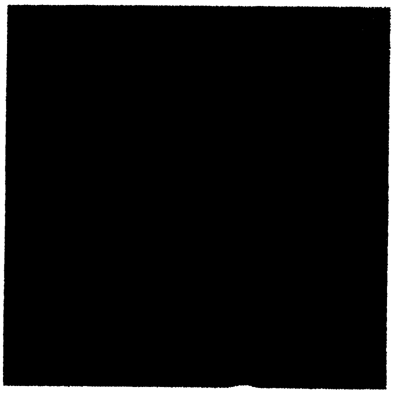


Figure 2. Optical micrograph of polycarbonate piece that was used as a mold for the present method (obtained from a compact disc of SAMSUNG-make).

In Figure 3 we show optical micrograph of the etched parallel lines on glass as imprinted by stamping of HF on the surface.

As evident from the figure continuous long range parallel alternate dark and light colored lines can be seen running from one end to the other. This shows that good quality etching could be obtained using this method. The width of each light colored line is about 0.7 mm that is nearly equal to that of CD mold, while the width of each dark line is about 0.8 mm and that is nearly equal to the separation of two parallel lines of the CD mold.

The imprints of parallel channels via chemical etching using the mold was further confirmed by scanning electron microscopy. In Figure 4 we show the scanning electron micrographs of two separately etched glass samples. The dimensions of the lines representing etched channels and non-etched crests match with those of the negative replica of the mold. Thus the present method produces submicron scale parallel long channel structures.

Figure 3. Optical micrograph of an etched glass slide. The slide was etched by HF solution using polycarbonate disk of a CD as the mold. Bar is 10 μm

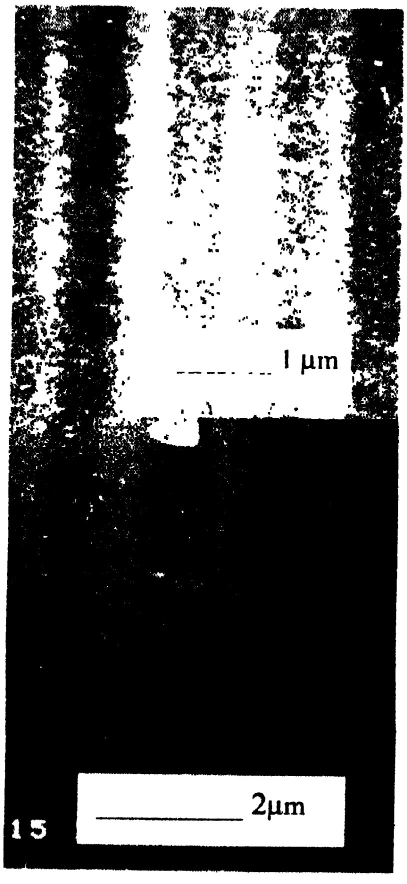
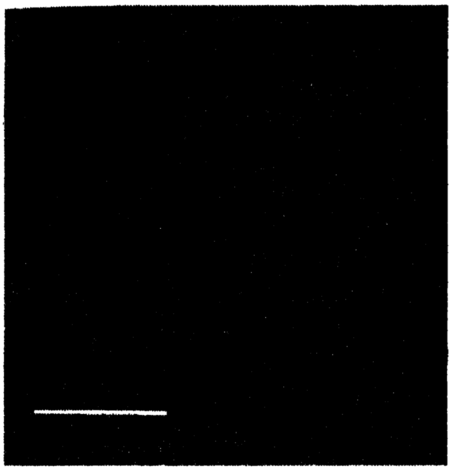


Figure 4. SEM images of parallel lines obtained by etching glass employing the present method

In Figure 5 we show the optical micrograph of a cross pattern generated on a glass surface as a result of stamping twice in quence using HF-inked mold. In this case, at first parallel line ›rns were generated as in Figure 3 by stamping the inked ıold onto a microscope glass slide. The slide was then washed ıth water and dried. That was followed by stamping for a ›cond time at an angle to the previous one. The rest of the rocedure was followed as before. Here also distinct features f the stamp-etched surface can be seen in the micrographs. he dark areas represent the non-etched parts of the slide while ıe brighter areas are the channels formed due to etching. A ›pical dark spot here has an area of about 0.64 $(mm)^2$ as expected om the dimensions of the mold.



gure 5. Optical micrograph of a cross pattern generated by etching the rface twice in sequence at an angle using polycarbonate mould. Bar is 10 n

We also wanted to learn how the etching takes place using ese nanoscopic patterned polymer discs. There are two ›ssible mechanisms by which the patterns could be generated. ıe first is by only the "crests" of the mold upon inking nerated these patterns by chemical etching of glass. On the her hand there is a possibility of aqueous HF solution from e swab draining into the channels thus filling them in addition inking the "crests". Thus the etching process would take ace both by the "crests" of the mold and the filled channels. is might seem to inhibit fulfilling our aim of producing noscopic lines instead would produce an etched surface with features. As this was not the case the reason for obtaining e channels and cross patters as we did is as follows. Both the rests" and the filled channels etch the glass plate. As the annels have much more volume of solution than the "crests" uld possibly have the regions of glass plates in contact with e filled channels would be etched more than the regions in ntact with the "crests" thus producing the patterned channels. verify this we did the following experiment. We spin coated glass plate with a thin film of polystyrene. We then cut two dely separated parallel channels on it using a razor blade. We en rubbed the HF "inked" swab against the film once in rpendicular to both channels and on the plane of the film. A ass plate was then pressed on this film. In case the HF solution went into the channels it would produce an "H" letter shaped etching on the glass covering the film; otherwise it would produce a single line with the dimension of the original ink-line. As shown in Figure 6 we observed the formation of an "H" shaped mark on the glass plate thus proving that indeed etching of glass took place by HF present in the "crests" and filled channels of the mold.

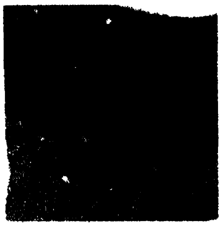


Figure 6 Photograph of the macroscopic "H" shaped mark on glass plate due to etching of glass

4. Conclusion

In this communication we have been able to clearly demonstrate the ability to make sub-micron scale two-dimensional stamp-etching of glass surface by simply wetting the mold (polycarbonate membrane of a CD) with the etching solution followed by stamping on the glass substrate. The etched channels appeared as parallel lines as seen in optical and scanning electron microscopy. The etched lines were a reproduction of the negative replica of the mold. We also could make arrays of etched dots on the surface at a predetermined angle. The present method is advantageous compared to other methods of generating submicron scale structural patterns on glass sample. It is a straightforward method and also cost effective. By using the present method one can reduce the number of steps involved thus reducing the cost of production of submicron scale channel structures on glass substrates.

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